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Making fire work: pyrotechnics and natural philosophy

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Everyone is familiar with fireworks, common to festivals and celebrations across the world. At first glance, the history of science might appear to have little to do with the history of these explosive devices. However, fireworks were an important element of court culture in Europe, which relied on spectacle and festival to manifest the power of princes. From the fifteenth century, courts regularly set off fireworks around elaborate theatrical scenery and ephemeral temples, fascinating audiences with a variety of exotic motions and effects exploding in the night sky. Fireworks also intrigued natural philosophers, and over several centuries there were diverse interactions among the sciences and pyrotechny.

Artificial apocalypse

> "It seems as if the whole city is on fire... as if the sky has opened...it seems as if all the air in the world is filled with fireworks, and all the stars in the heavens are falling to earth – a thing truly stupendous and marvellous to behold [1]."

This is how, in 1579, the engraver Giovanni Ambroglio Brambilla described the Girandola festival in Rome, an event staged for the election of a new Pope at the Castel Sant'Angelo from the fifteenth century onwards and one of the earliest displays of fireworks in Europe (Figure 1) [2]. The idea of the stars falling from heaven alluded to the Biblical apocalypse (Matthew chapter 24, verse 29), a sign of the return of Christ after the end of the world, and a suitable image for the transition between papal reigns.

Historians of science have long suggested that the arts contributed practical and observational skills to science during the sixteenth and seventeenth centuries. The history of interactions between science and pyrotechny elaborates this picture, suggesting an ongoing, reciprocal and dynamic exchange both during and after the scientific revolution. Making fireworks involved many different skills: artists, artillerists, natural philosophers, poets, engineers and administrators all participated in creating displays. As each of these different communities vied to claim fireworks as their own, there was plenty of uncertainty over the definition and status of pyrotechny before, during and after the scientific revolution. Was it an art or was it a science?

Tracing the shifting configurations of fireworks and science between the sixteenth and nineteenth centuries offers an intriguing glimpse into ongoing debates about what it was to do "science" or "art" and reveals the diversity of historical relations between arts and sciences.

Wondrous fire

In Europe, fireworks started out as "artificial fires" imitating Nature. Indeed, the French still know them as *feux d'artifice*. In their efforts to imitate Nature's fiery effects, early modern Gunner-artisans used pyrotechny to represent "stars", "comets", "fiery rains", "suns" and many other celestial phenomena that deeply impressed their audiences.

This notion of fireworks as artificial meteors was an expression of the Renaissance idea that art could be used to imitate and cultivate Nature into an "artificial" or "third Nature". Nature was not a homogeneous and regular entity but a personified and playful agent, whose imitations of the ideal forms of the divinity were themselves capable of imitation by humans. The chaos of obscured boundaries between the products of art and Nature led to wonder and pleasure on the part of spectators, an aesthetic that lay behind cabinets of curiosities, artificial fountains, grottos, natural magic and pyrotechny, all of which played on artful imitations of Nature and helped shape natural philosophy in the seventeenth century [3].

For example, magicians like Neapolitan Giambattista della Porta often included recipes for fireworks in their books of natural magic, and these were inspirational to revolutionary thinkers like Francis Bacon. Indeed, in his utopian *New Atlantic*, Bacon envisaged an ideal scientific institution – Solomon's House – in which practical and artful imitations of Nature might lead to human progress and the "advancement of learning". He located fireworks in the "engine house" of Solomon's House, along with clocks, perpetual motions and automata.

> We represent also Ordinance and Instruments of War, and Engines of all Kinds, and likewise new Mixtures and Compositions of Gun-Powder, Wild-Fires burning in Water and Unquenchable: Also Fire-Works of all Variety, both for Pleasure, and Use... We imitate also Flights of Birds; We have some Degrees of Flying in the Ayr... We imitate also Motions of Living Creatures, by Images of Men, Beasts, Birds, Fishes, and Serpents; We have also a great Number of other Various Motions, strange for Equality, Finenesse. and Subtility [4].

Fiery machines

In the seventeenth century, fireworks were widely thought of as machines, so also had an influence on the new

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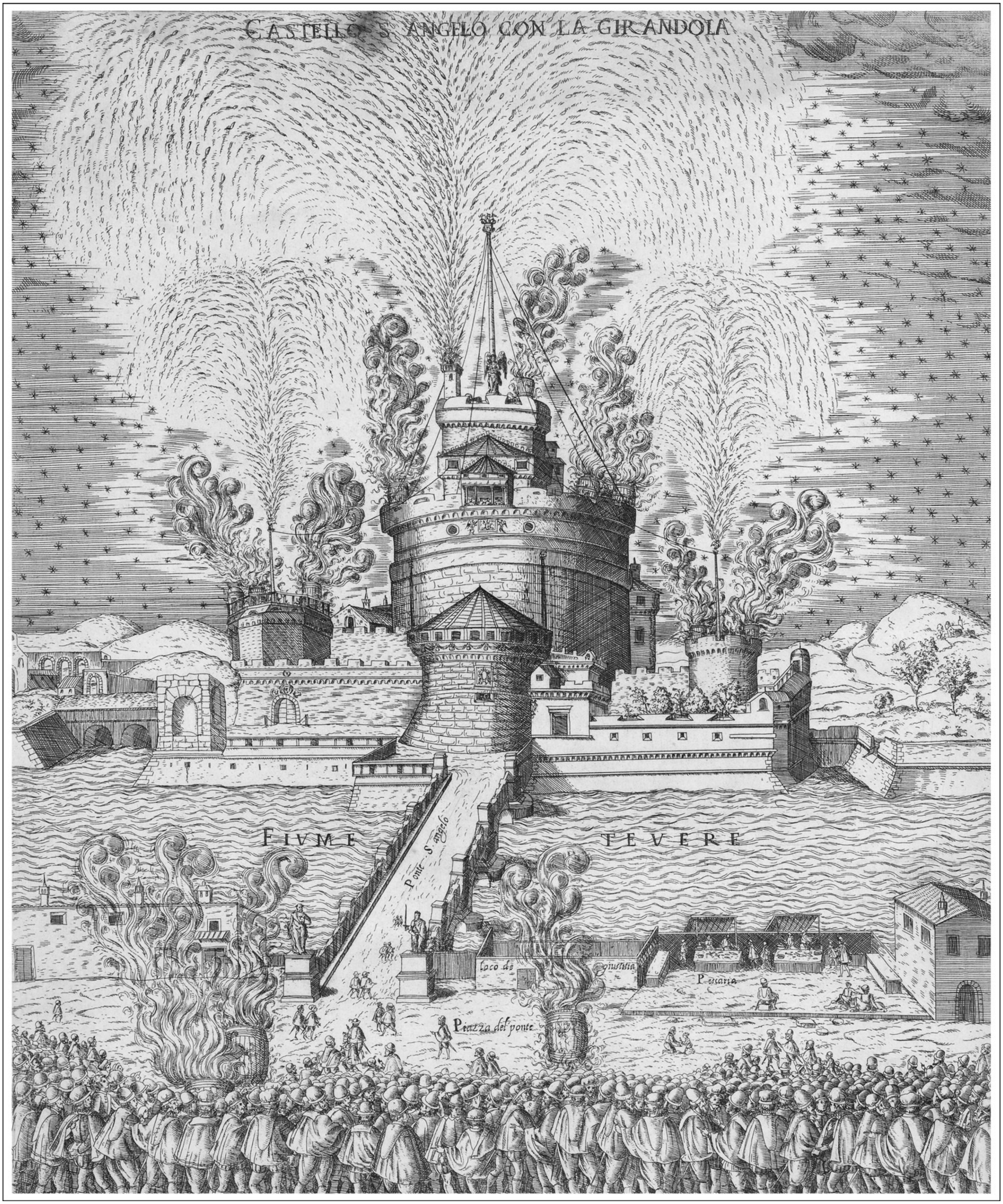

Figure 1. An engraving of *Castello S. Angelo con la girandola* by G. A. Brambilla from 1579. The wheatsheaf shape of exploding rockets over the Castel Sant'Angelo gave the Papal ''Girandola'' festival its name. Research Library, The Getty Research Institute, Los Angeles, California (91-F104).

"mechanical philosophy" of Nature's operations. For Robert Boyle, the mechanical universe was analogous to a grand fireworks display, while Leibniz took fireworks as a model for his system of "pre-established harmony" in which God ordered everything to unfold like clockwork, or in this case like fire-work. In his *Theodicy*, Leibniz attacked the suggestion that a ship's path could not be predicted, even by God, explaining that, "as God orders all things at once

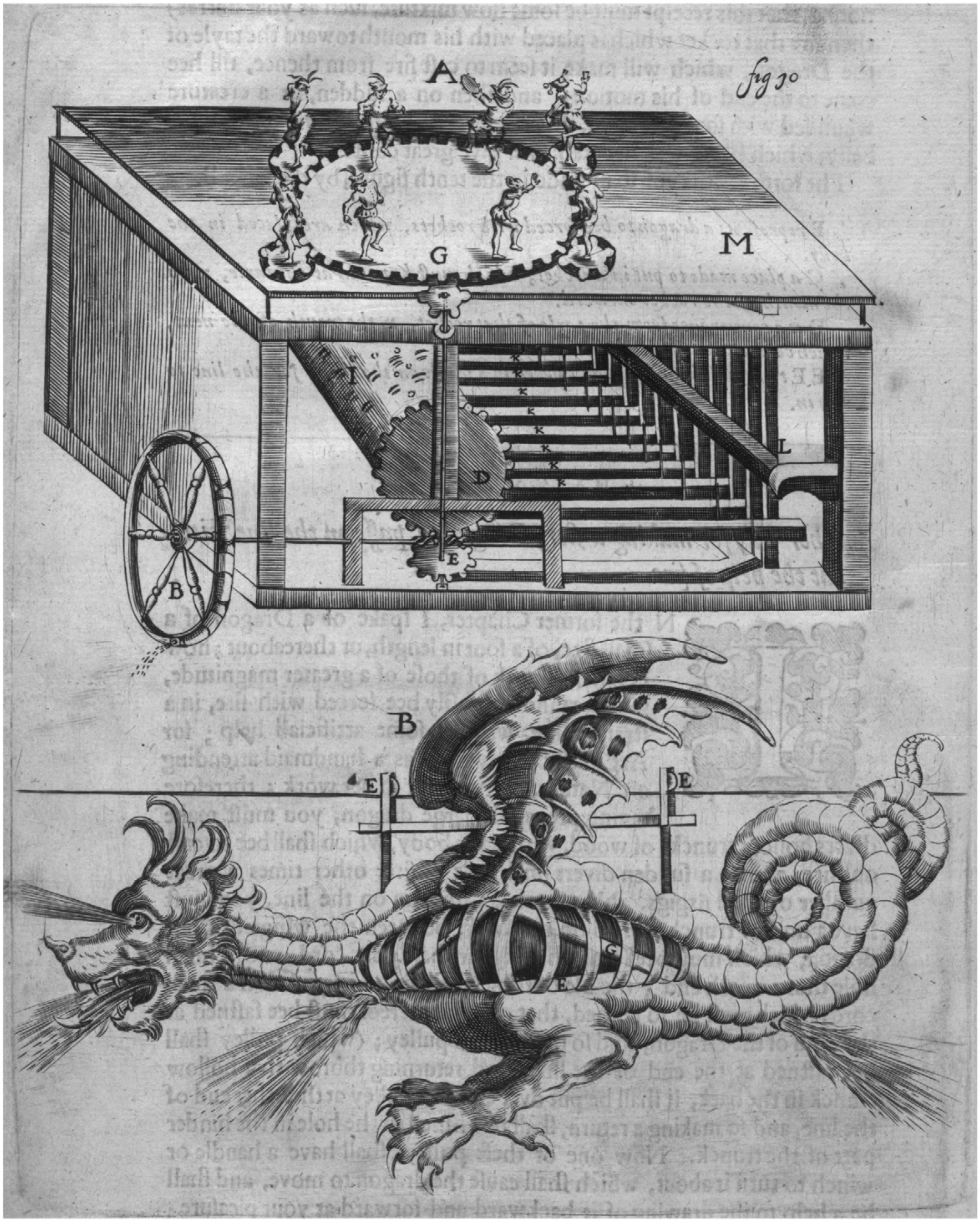

Figure 2. An illustration from John Babington's *Pyrotechnia* (London, 1635) shows the ''flying dragon'', here located next to an automaton, suggestive of the mechanical identity of fireworks at this time. Reproduced, with permission, from the Edgar Fahs Smith Collection, University of Pennsylvania Library.

beforehand, the accuracy of the path of this vessel would be no more strange than that of a rocket passing along a cord to a firework, since the whole regulation of things preserves a perfect harmony between themselves by means of their influence one upon the other [5]." Leibniz had in mind a particularly popular firework of the seventeenth century, the "flying dragon." Originally an imitation of a fiery meteor, by the mid-seventeenth century the dragon appeared as a wood and paper figure propelled back and forth along a cord between two towers by rockets (Figure 2).

If sixteenth-century fireworks played on the boundaries of art and nature to produce marvels, seventeenth-century fireworks continued to create miraculous effects, but now signified the exceptional powers of the absolutist prince. Francis Bacon told King James I at the beginning of the seventeenth century that when all other miracles ceased, through the rise of science, the King would be the only miracle remaining [6]. By the end of the seventeenth century, Louis XIV used fireworks to present himself in precisely this manner. Whilst mechanical philosophers in the king's academy of sciences were busy demonstrating that Nature was not in fact playful but behaved in a regular, predictable manner according to divinely ordained laws, royal fireworkers manufactured miraculous acts that turned the king into the only natural magician in an otherwise clockwork state. For the court poets, Louis became an alchemist, transmuting the elements in fireworks:

> All that was seen in this great stretch of more than three hundred fathoms was no longer either fire, air or water. These elements were so mixed together that they became unrecognisable and there appeared a new one of a most extraordinary nature. It seemed to be a composite of a thousand sparks of fire, which as a thick dust or, rather, as an infinity of atoms of gold shone in the middle of a greater light [7].

Nevertheless, the wonder that fireworks induced in spectators during the Renaissance had, by the early eighteenth century, begun to give way to a different, more tempered response. Members of the court of Louis XV were encouraged to be *nonchalant*, literally 'not heated', and audiences were increasingly capable of exerting control over their fiery passions (Figure 3). Such forms of spectatorship offered models for witnessing Nature. Natural philosophers of the eighteenth century often referred to Nature as a great "spectacle", while philosophical audiences were also shown as dispassionate in the face of Nature's marvellous effects.

Enlightened pyrotechnics

By the late seventeenth century, both fireworks and natural philosophy had become institutionalized. European states founded academies for science and arsenals for fireworks, where artillerists made fireworks in workshops known as "laboratories". This led to numerous interactions between natural philosophers and artisan-fireworkers in the eighteenth century, although the nature of interactions tended to be different in different locations.

In England, for example, experimental philosophers often interacted with artisan-fireworkers on a practical level, using fireworks in experimental investigations. John Theophilus Desaguliers, the Newtonian curator of

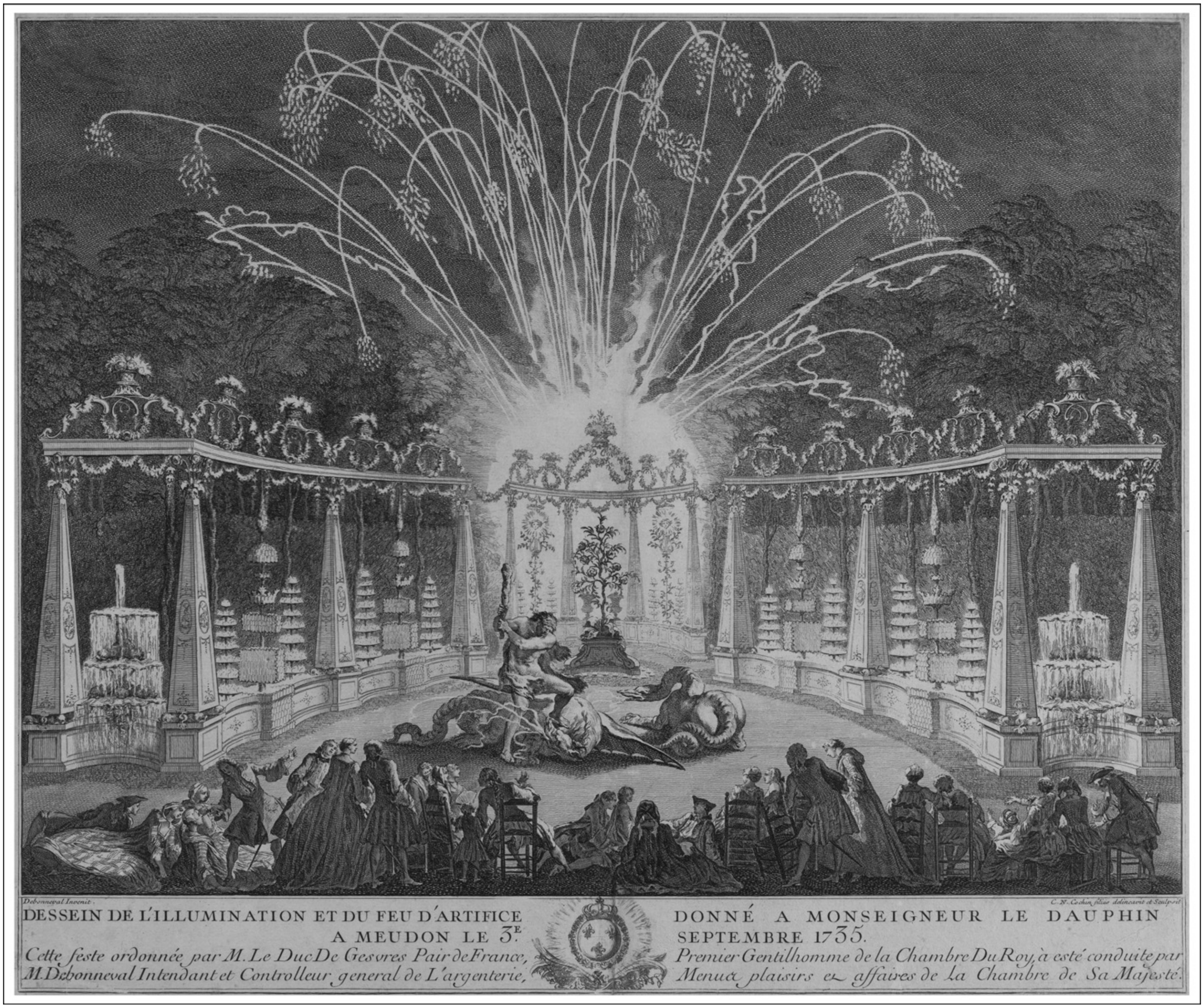
Debonneval Invenit.
C. N. Cochin filius delineavit et Sculpsit
DESSEIN DE L'ILLUMINATION ET DU FEU D'ARTIFICE DONNÉ A MONSEIGNEUR LE DAUPHIN
A MEUDON LE 3E SEPTEMBRE 1735.
Cette ſeste ordonnée par M. Le Duc De Geſvres Pair de France, Premier Gentilhomme de la Chambre Du Roy, à esté conduite par
M. Debonneval Intendant et Controlleur general de L'argenterie, Menus plaisirs et affaires de la Chambre de Sa Majesté.

Figure 3. In *Dessein de l'illumination et du feu d'artifice a monseigneur le dauphin à Meudon le 3e septembre 1735*, courtiers are depicted as nonchalant, conversing, relaxing and apparently oblivious to the spectacular explosions of pyrotechnics overhead. Research Library, The Getty Research Institute, Los Angeles, California (P950001**FF.28).

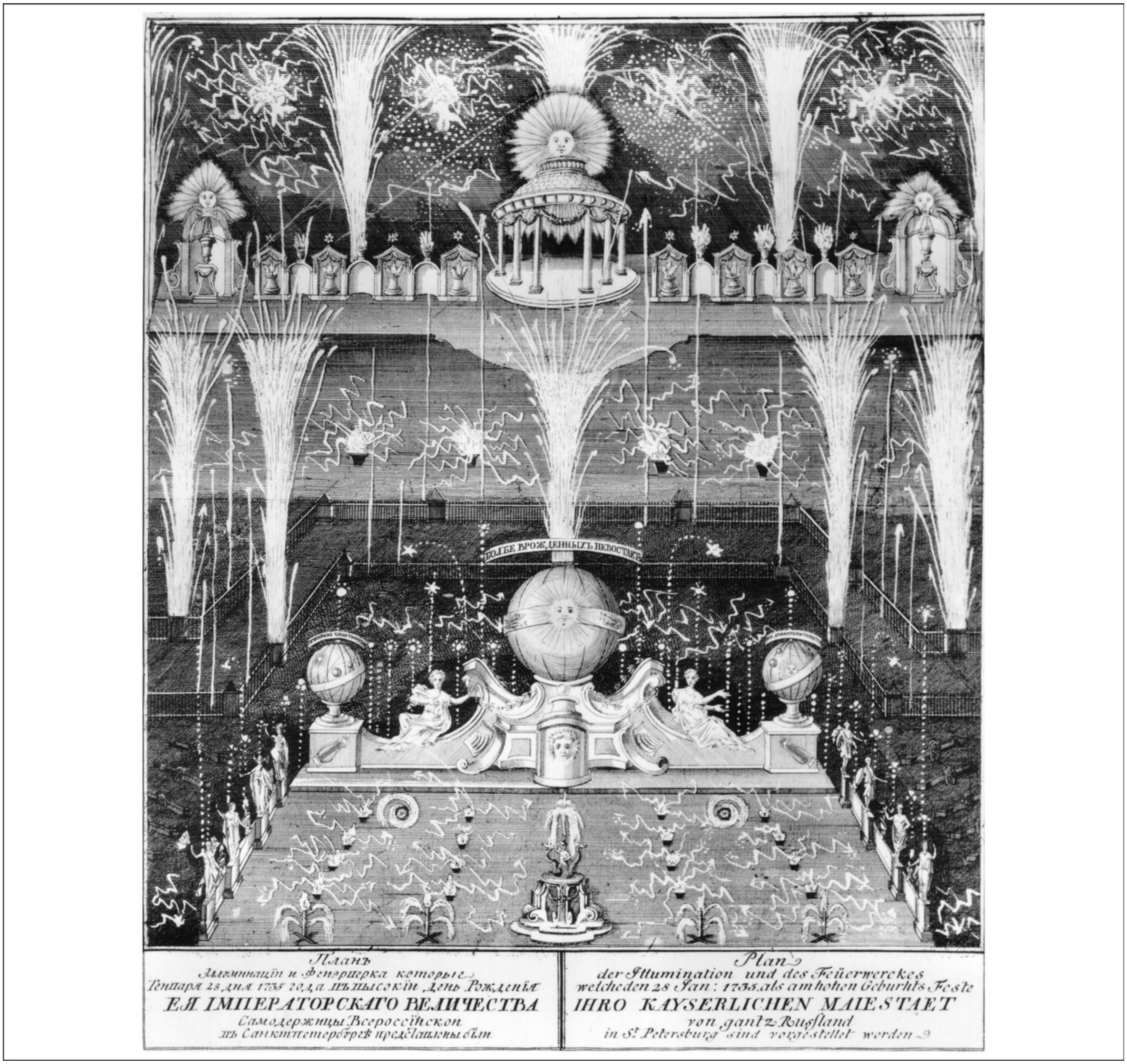
Планъ
Иллуминацїи и Фейерверка которые
Генваря 28 дня 1735 года въ высокїй день Рожденїя
ЕЯ ІМПЕРАТОРСКАГО ВЕЛИЧЕСТВА
Самодержицы Всероссїйской
въ Санктпетербургѣ представлены были
Plan
der Illumination und des Feüerwerckes
welche den 28 Jan: 1735. als am hohen Geburths Feste
IHRO KAYSERLICHEN MAIESTAET
von gantz Rußland
in St. Petersburg sind vorgestellet worden

Figure 4. A Russian fireworks display of 1735 showed Russian audiences the cosmological systems of Tycho Brahe and Nicolas Copernicus, rarely seen in Russia before this time. Anon. (1735) *Kratkoe iz'iasnenie izobrazheniia onago feierverka i illuminatsii kotorye v' chest' eia imperatorskago velichestva samoderzhitsy vserossiiskiia v' vysochaishii den' eia rozhdeniia 28 Genvaria 1735 goda pred' imperatorskimi palatami v' Sanktpeterburge zazhzheny byli*, engraving. Reproduced, with permission, from the Sächsische Landesbibliothek, Staats- und Universitätsbibliothek, Dresden/Deutsche Fotothek.

experiments at London's Royal Society from 1716, not only experimented with fireworks to understand the nature of explosions underwater, but also put on firework displays for his patron, Frederick, Prince of Wales. In 1738, Desaguliers set off pyrotechnics around a statue of King William III in Bristol, in three 'acts', the last of which centred on a twenty-foot high pyramid and a blazing sun [8].

At Russia's Academy of Sciences in St Petersburg, by contrast, experimental philosophers steered well clear of interactions with artisan-fireworkers. The Russian Academy, founded in 1725 to bring science to the Russian empire, drew a sharp distinction between those who worked with their heads and those who worked with their hands. Russia's academicians left practical activities mostly in the hands of paid mechanics and artisans in the institution. Fireworks were no exception. Throughout the eighteenth century, the Russian court called upon the Academy to design firework displays that were built and put on by the city's artillery corps. In their efforts to boost their standing in the eyes of ordinary Russians, who were frequently hostile or apathetic towards the sciences, academicians worked hard to obscure the contributions of artisan-fireworkers: they published descriptions and engravings of fireworks, which routinely celebrated their allegorical content but rarely mentioned the artillerists and artisans who turned academic designs into reality; and images of displays never showed the skilled hands that set them off (Figure 4).

As the eighteenth century progressed, the rise of a middle class or "public" that increasingly consumed private, domestic or commodified entertainments also had an influence on the relationship between artisans and natural philosophers. This audience consumed both philosophical and pyrotechnic goods, attending lectures and courses on natural philosophy, purchasing books and scientific instruments, and spending leisure time in parks and pleasure gardens, where fireworks were increasingly shown to paying audiences in the second half of the eighteenth century.

In this era of enlightenment, as such "rational recreations" proliferated, it became common for practitioners to engage in both science and fireworks. The Milanese Giovanni Battista Torré, for example, made barometers with Paris academician René-Antoine Réaumur, gave lectures on physics and chemistry, and became one of the most successful performers of fireworks in the eighteenth century.

In Paris, there was also much collaboration between chemists and pyrotechnic artists, who sought to include new philosophical effects in fireworks. Antoine Lavoisier, for example, gave advice on fireworks made with the newly discovered "inflammable air" (eventually identified as hydrogen) to several fireworkers in the 1780s. These included the Ruggieri family, who had travelled from Bologna to Paris in the 1740s to exhibit fireworks, and who contributed much to the integration of science and pyrotechny. Family members invented an asbestos flameproof suit, experimented with firing animals into the air with rockets, and produced the first "scientific" book on fireworks, Claude-Fortuné Ruggieri's *Elémens de pyrotechnie*, in 1802 [9].

Such "philosophical fireworks" proved significant for the industrial revolution. Inflammable air fireworks, for example, led directly to early schemes for lighting streets, homes and factories with gas, and the first gas-lights were promoted as both sources of heat and light, and as a means to create impressive spectacles.

The science of fireworks

For most of the eighteenth century, it had been the painters, architects or men of letters designing displays who had been considered most important for the success of courtly fireworks; the pyrotechnists who set them off received little credit.

In the first decade of the nineteenth century, Claude-Fortuné Ruggieri sought to change this by claiming in his *Elémens de pyrotechnie* that pyrotechny was above all a science, demanding knowledge and skills in physics and chemistry. Skills in art, architecture or letters, according to Ruggieri, were valuable, but not sufficient to make a true pyrotechnic artist. Ruggieri's views proved influential, and from the early nineteenth century, pyrotechny came to be seen as a form of "applied chemistry." This elevated the status of pyrotechnists and gradually did away with the elaborate allegorical designs and theatrical input of artists and architects, leaving firework spectacles free of scenery as they are experienced today.

Simultaneously, pyrotechnists came to defer to professional chemists as the experts on innovation in fireworks. Scientists such as the Philadelphia chemist James Cutbush thus made experiments in the 1820s to produce new colours and effects in pyrotechny, which were incorporated into pyrotechnists' displays [10]. This arrangement set the pattern for a relationship of science and fireworks that has endured ever since.

Finale

The shifting identity of fireworks thus reveals something of the ongoing, reciprocal and dynamic nature of interactions between an art and the sciences in early modern Europe. Between the Renaissance and the early nineteenth century, fireworks stood at the intersection of a variety of artistic and scientific practices and ideas, from the marvellous cultivation of Nature's powers in artificial imitations of meteors to the skilful deployment of physical and chemical science to produce new effects. Fireworks fed into the new experimental and mechanical philosophies of the seventeenth century, confirming notions that artisanal skills helped reshape natural philosophy towards more practical ends in this period.

Fireworks also continued to affect the fortunes and forms of natural philosophy in the eighteenth and nineteenth centuries, earning credit for the St Petersburg Academy, offering models of spectatorship for observing Nature, or supplying new effects such as gas-light which later emerged as industrial technologies. Simultaneously, natural philosophers contributed to fireworks, advising on new methods, creating novel mixtures and colours for pyrotechnics, and giving practitioners credit as pyrotechny began to be represented as a science. The case of fireworks is thus indicative of an enduring and multifaceted relationship between the arts and sciences since the Renaissance, one that will no doubt continue to flourish and move in unexpected directions.

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